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THE FRANZ EDELMAN AWARD
Achievement in Operations Research

Operations Research Improves Quality and Efficiency in Home Care

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Elder care systems are facing increased costs, primarily because the elderly constitute a growing percentage of the population. Sweden publicly finances such systems; in 2005, the cost to taxpayers on a national level was 8.8 billion euros ($13 billion). The many customized aspects of scheduling home care workers to assist elderly and disabled citizens with their varying needs contribute to these costs. Laps Care, a system that was developed in 2002, uses operations research modeling to eliminate the manual planning of home care unit assignments. More than 200 units/organizations in Swedish municipalities use Laps Care each day to plan staff scheduling and routing for 4,000 home care workers. The system has increased operational efficiency by 10–15 percent; this corresponds to an annual savings of 20–30 million euros ($30–$45 million). In addition, the quality of home care for elderly citizens has improved. The City of Stockholm, with its 800,000 inhabitants, adopted Laps Care in 2006 and started a full implementation and rollout during 2008, thus adding 800 units and 15,000 home care workers to the system. The savings for the City of Stockholm will be 20–30 million euros ($30–$45 million).

Key words: health care; decision support system; heuristics; scheduling.

Anna, 89, found dead after missed home care services.
My mother met 57 different persons from the home care services during the last two months.

Sick leave among staff members above 30 percent in the elderly care.

These are the headlines that every client, client relative, home care staff member or manager, and responsible politician dreads to see published in the local papers. While similar headlines appear in Swedish newspapers occasionally, thanks to an operations research-based system, they are now avoidable. Laps Care, a system that was developed in 2002, uses operations research modeling to eliminate the manual planning of home care unit assignments. More than 200 units/organizations use Laps Care every day to plan staff scheduling and routing for 4,000 home care workers. The system has increased operational efficiency by 10–15 percent. This corresponds to an annual savings of 20–30 million euros ($30–$45 million) and improves in the quality of home care for elderly citizens.

The objective of home care operations is to provide high-quality home care services to the elderly living at their own homes; however, limited resources and a complex planning situation complicate the scheduling process. The organization and financing of home care for elderly citizens differ between countries. Sweden finances this care through taxes; the local government (i.e., city council) has financing responsibility. In 2005, this care cost 8.8 billion euros. The care can be given either by permanent staff in retirement homes or by home care staff scheduled to visit clients' homes. The latter is much less expensive.

On average, a place in a retirement home costs 49,500 euros annually, whereas home care costs 20,300 euros. Thus, we can see that helping people in their homes is generally less costly than moving them into retirement homes. Furthermore, it also has a positive effect on their quality of life. Therefore, a goal of local government is to increase the proportion of care performed at home.

Home care and home health-care services differ. Although they sound the same (and home health care might include some home care services), home health care is more medically oriented. *Home care* involves helping the elderly with everyday activities, such as bathing, dressing, and eating; it could include assistance with cooking, cleaning, and other housekeeping tasks, and monitoring the daily medication regime. *Home health care* usually involves helping clients recover from an illness or injury. Thus, the people who provide home health care are often registered nurses, therapists, or home health assistants. In the article, we will primarily use the term home care, although the users of the planning system, Laps Care, might also be performing home health care.

The demographics in Sweden are similar to that of the rest of Europe. In the coming decades, fewer workers will be responsible for providing social care for a growing number of elderly people. The elder care sector is labor intensive; in 2005, approximately 250,000 people were employed in this sector, and of these, about 88,000 full-time equivalents, employed by public and private companies and organizations, were involved in home care. To put this into perspective, home care employees constitute 2 percent of Sweden's work force. Introducing modern information and communication technology (ICT) solutions is in accordance with the political focus, which highlights freedom of choice and higher-quality social care.

In 2001, the Home Care Department in the City of Danderyd started a review of its home care planning process. It was clear that the daily planning of the integrated staff scheduling and routing was a difficult problem and that there was a need for planning tools to assist the planners. Together with Optimal Solutions AB, a software company, it developed a planning system that included a geographical information system (GIS) and an operations research-based solver for the planning problem. This system became Laps Care software, which has been in daily use in Danderyd since November 2002. Optimal Solutions then marketed Laps Care to home care organizations in all Swedish municipalities. Approximately 10 organizations implemented the system during its first year on the market. In 2004, TietoEnator, a large Nordic IT company with 17,000 employees in 30 countries, became a selling partner for Laps Care. TietoEnator has since developed several applications in the public sector. The Laps Care system complemented its selection of social care applications.

Since 2002, more than 200 systems have been put into operation in 50 Swedish municipalities (and a few Norwegian municipalities). These municipalities have created a user group, Forum Laps Care, which organizes meetings and provides feedback for further development of the system. In 2006, the city of Stockholm issued a public tender for a system to plan its home care resources of about 15,000 staff members in 800 units. Optimal Solutions and TietoEnator jointly won the tender. Because of the city's size and other demands on the integration of support systems, a new third-generation version of the software was developed and has been in use since the fall of 2007. Parallel to the Stockholm tender, TietoEnator acquired the Laps Care division from Optimal Solutions.

There is a wide variety of Laps Care customers. In this paper, we describe and discuss results and experiences from two local government organizations and from the Forum Laps Care. The first customer we will discuss is the City of Stockholm, a city of almost 800,000 people of different origins. Its 2008 budget was approximately 3.9 billion euros ($5.7 billion), and it employs 47,000 people of whom 60 percent work within social care. Social care, including home care to elderly citizens and disabled persons, is the city's most expanding activity. The second customer we will discuss is the Linköping Municipality. Linköping is the fifth-largest city in Sweden with 130,000 inhabitants. Home care activities are competitive and are currently split 50–50 between private organizations and the municipality's home care department. In Linköping, 11 home care units employ 350 home care workers to serve 1,200 citizens; Laps Care is used to schedule their assignments on a daily basis. These staff members provide 24,000 home care hours each month.

Figure 1: This figure illustrates the three main components in the planning process. The process begins with a need by an elderly citizen (top); the citizen and the health care organization (right) within the municipality agree on a social service assignment that home care workers (left) will perform later.

The Operations and Planning Process for Home Care

Long-Term Planning

When elderly or disabled people in Sweden need care to manage their everyday lives, the local authorities have a legal obligation to provide it. In Figure 1, we show the major components of the home care operations.

The Social Welfare Act regulates the types of services to be given and what the client should pay. Home care is financed by local taxes and, to a small extent, by client fees. If a client cannot pay, assistance is available.

The services that elderly people receive in their homes include home cleaning, food purchasing, and other household tasks. Many of the services include help with more personal tasks, such as getting up in the morning or going to bed at night, showering, and shaving. They might also include the delivery of food and help with eating. Home care also might include doctor visits, ensuring that medicine is taken, and medical care.

To receive home care, the citizen must contact the local authorities and then meet with a social services officer. An assessor determines the help that the person needs. This is normally done on an aggregate level, i.e., two showers a week, four hours of cleaning, or 30 hours of daily care per month. The result is a care plan that lists the types of services to be performed and the amount of time to be allocated. The care plan does not normally state when a specific service should be provided. It is up to the provider and the elderly person to agree upon the details of the care plan. The result of this process is a visit plan that states when each visit should be performed. While the local authorities usually provide the service, private contractors might also provide it.

Providing care in people's homes is complex and difficult to plan. At the same time, the activities must be of high quality for both the elderly and home care workers. Home care operates 24/7 and is continuously changing. The assignments change frequently for various reasons; for example, elderly clients require more help when they get sick and none at all if they temporarily move into a hospital. The services operate over the entire municipality. The employees have different backgrounds, and many have special skills that enable them to perform certain tasks. For example, only a registered nurse can give insulin shots. The home care organizations have traditionally used manual planning, a time-consuming task. Frequently, additional staff is needed to handle all the visits. In addition, the quality of the planning could be low, from both the staff and client perspectives. Decision-support systems (DSSs) have the potential to improve these operations. We will demonstrate that LAPS CARE can improve administration, reduce planning time, reduce transport and waiting times, and improve the quality of the service.

Operational Planning

Home care activities in a municipality are organized into a number of home care units. Stockholm has approximately 800 home care units; typically, 15 to 30 people work in each unit. Because the majority of the tasks are performed according to a schedule and in regular intervals, there is a base plan. In this base plan, each task is assigned to a specific staff member on a schedule that normally repeats on a four-week cycle. The base plan is rarely reconstructed completely; however, changes are made by inserting new tasks when a new client is assigned to the unit or when a client needs a modification. To give them a better overview of the base plan, the staff and clients are divided into geographical subareas. This simplifies planning; however, developing efficient plans by resource sharing becomes more difficult.

Although the base plan is seemingly stable, frequent changes occur. Needs change daily; for example, a client might go into a hospital or go to visit family. These changes are noted and collected for handling. Each morning, all staff members gather in the home care office. During these meetings, last-minute changes are addressed. For example, if an employee has called in sick, the unit manager must decide whether to call in a replacement or to try to fit the tasks into the routes of the other workers. Some tasks, such as cleaning, can be postponed to a later day. Furthermore, these discussions are often intensive; people who speak well or have dominant personalities often control the changes. Thus, it becomes difficult to meet the goals of scheduling the person with the right competence for the right visit at the right time with the highest quality at the lowest cost in only a few minutes.

Some tasks are more time-critical than others. Insulin shots must be delivered at the correct time for medical purposes. Morning help must also not be delivered too late, whereas cleaning is more flexible. Even tasks that might not be time-critical have time windows because the clients should be able to plan their days; they are dependent on the staff following the agreed schedule within reasonable limits. Some tasks, such as heavy lifting, also require double staffing. Specific tasks require special skills, such as language or medical qualifications; thus, it is not always easy to replace one staff member with another.

The nature of the services delivered is usually distributed unevenly during the day. The workload tends to be much greater in the morning than in the afternoon. Therefore, work schedules are individual, and part-time employees are common. The sizes of the geographical areas covered could differ greatly. Some units work only within a small neighborhood, and staff members can walk or bike to their clients. In rural areas, clients might live 40–50 km away; thus, staff must drive to them. However, some staff members do not have driving licenses, and the number of available cars is limited. Most units use a combination of all three transport types.

Operations Research Modeling

The staff planning involves finding a feasible working plan for all staff to be able to meet both hard and soft constraints. Hard constraints might be regulations on working hours and qualification requirements. Soft constraints might be staff or client preferences. In addition, there is a routing component because the visit locations can be very geographically dispersed. Therefore, it is important to consider the time windows of visits, travel costs, and times using different transportation modes (e.g., walking, bicycle, car, or bus). This problem is similar to a vehicle routing problem (VRP), including time windows, with home care visits interpreted as node visits and individual staff members represented by vehicles. Our problem has one important criterion: to quickly generate high-quality solutions.

There are many restrictions on the staff scheduling and routing. A visit is described by the tasks to be performed, the time window within which they must be performed, and the set of skills required by the health care worker. Specific visits are grouped in such a way that the same staff member must do all visits. Some visits are unusual in that they require two (or several) members. Each employee has given working areas, numbers of working hours, and planned breaks, such as meals. Sufficient travel time between visits must be allocated within each individual's route. Travel time also depends on the transportation mode that the staff member uses. To meet these objectives, several aspects must be considered and weighted. Each client has one or more preferred staff members. Moreover, the number of individuals who visits each client should be minimized. Each employee should be allocated visits according to his or her preferences, and the workload distribution between staff members should be even and fair. In addition, the number of extra staff should be minimized.

There are many approaches to solve staff scheduling and rostering problems. A survey by Ernst et al. (2004) reviews problems in specific application areas and the models and algorithms that have been reported in the literature for their solution. There are few articles that discuss home care or home health care. Begur et al. (1997) describe a DSS for the scheduling and routing of nurses in a home health-care application in the United States. This system integrates a GIS and an optimization package on a stand-alone PC. The planning period is five days, and no operative replanning is required. The routing problem is solved based on the familiar Clark and Wright (1964) heuristic. It reports some savings based on test results but no long-term quantitative savings from using the system. Bertels and Fahle (2006) describe the optimization models and methods used to solve a home health-care application in Germany. The optimization is based on a combination of linear programming, constraint programming, and metaheuristics. The planning period is one day, and the solution time is limited to 10–15 minutes. Hence, we can use it for operational planning. However, it does not include a DSS description or report real quantitative savings. The base model in the system is based on a set-partitioning model.

The Laps Care solution method is based on repeated matching, which is an optimization-based heuristic in which a series of matching problems are solved. Several routing and scheduling applications have applied this approach. Wark and Holt (1994) solve a general VRP; Forbes et al. (1991) solve a VRP for bus drivers. Eveborn et al. (2006) provide a detailed description of the methodology implemented in Laps Care; Eveborn et al. (2004) provide a more popular description of the problem formulation and the use of an earlier version of the system. There are some aspects that are particular to this application. Figure 2 describes the algorithm.

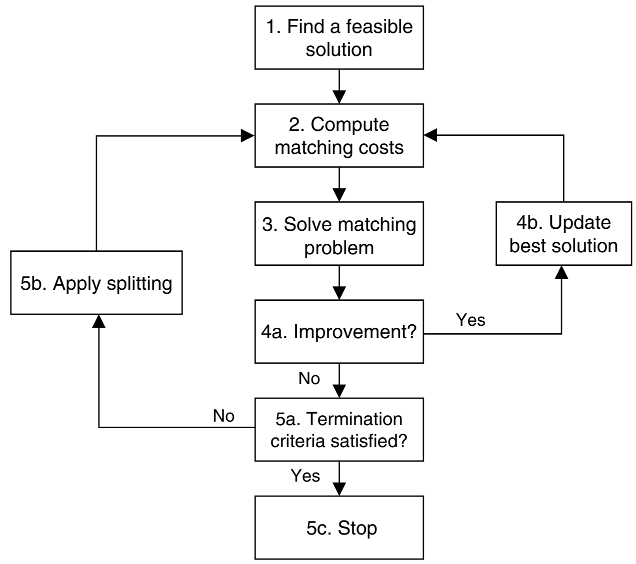


Figure 2: The repeated matching algorithm is an iterative method; in each iteration, the primary step is to solve a matching problem in which the solution represents a set of routes, one for each employee.

Laps Care Solution Method

In this section, we describe the steps that Figure 2 illustrates.

(1) First, we determine an initial solution. One solution is to use as many staff routes as there are visits.

(2) We then compute the matching costs d_{ij} by trying to pairwise match every element (route) i and j. A matching cost d_{ij} is the total cost of route i and route j after they have been matched together. We define a route cost as the time it will take for an employee to complete the route and a number of soft costs for evaluating quality, such as cost for the staff member who is assigned a specific task, the workload of the assignments, and area preferences. We define the total matching cost as the total cost for all the routes that the matching generated.

(3) The solution we found to the matching problem gives pairs of matched routes. Each pair corresponds to two routes where one or more visits have been moved between them. The computation of matching cost also involves ensuring that the employees have the appropriate competence for the visits. The solution to each matching problem provides a new solution.

(4) If we find an improved feasible solution, we update the best current solution and apply an iteration. If we do not find an improved solution, we check the convergence criteria; i.e., we check if any additional computational time is available. The repeated matching terminates when we reach a predetermined maximum number of iterations with no improvement, or when we reach a preset time limit.

(5) If we do not satisfy the convergence criteria, we apply a "splitting" technique; i.e., we divide or split the current best solution. A solution consists of subsets of elements; we can view splitting as dividing one or several subsets into smaller subsets. We split a route into as many routes as there are visits in the route. We continue the matching process and again match these subsets together. Splitting can therefore be viewed as a way to restart the process at another solution and hence avoid being trapped in a local optimum. Our implementation involves selecting a random route and removing all previously selected visits (in this route) to form new individual routes.

There are several challenges to solving the optimization problem. For example, a task that requires two staff members simultaneously, such as heavy lifting, also necessitates a dependency between routes that the standard VRP does not include. In the first version of Laps Care, we solved this by splitting the task into two tasks and using very narrow, identical time windows on both. However, because this limited our planning flexibility, we extended the approach. We incorporated this into the repeated matching by handling the relationship as soft constraints; penalties increased in the solution process until the related assignments were scheduled within feasible times that were relative to each other.

Bredström and Rönnqvist (2007) proposed a new approach in which they formulate the synchronized VRP into a new extended set-partitioning model and develop the solution approaches. The tests they report are based on home care applications. The fairness criterion is another aspect that requires additional modeling to relate routes to each other. However, one issue that remains to be addressed in the system is a flexible approach to allow several employees to carpool to complete their routes.

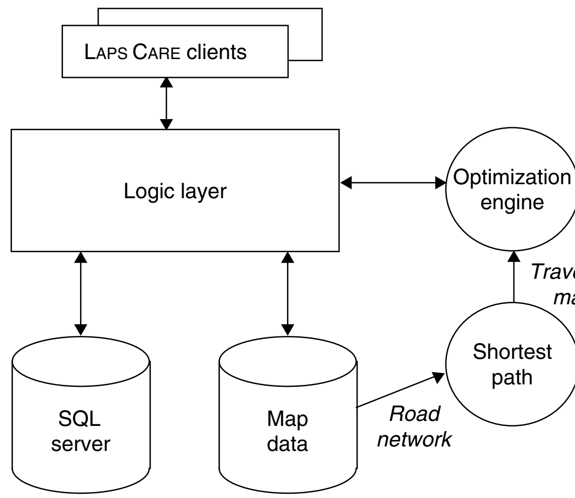


Figure 3: The logic layer within the Laps Care system provides the interface between planners, the databases with client and geographical information, and the optimization module.

Laps Care is structured around the workflow in the planning process, i.e., data registration, planning, and follow-up. Figure 3 describes the main components of the system.

The planner (i.e., user) registers the relevant data about the employees, the clients, and the visits that must be performed. In addition to the data, the planner enters travel-time estimates based on maps are needed for the planning algorithms to work. The travel times are computed automatically in a shortest-path routine that is based on a detailed geographical information system. The Laps Care system is built to support the planner. All data relating to visits and staff members are easily available and changeable through a set of input routines.

The system uses navigation maps that commercial suppliers have developed. Their principal use is in automobile onboard navigation systems; thus, the focus of data is on information that is useful for motorized vehicles. However, in our sector, much of our travel is on foot or by bicycle; some foot paths and cycle paths that the employees use frequently are not available in map data. Because the calcula-

Figure 4: The maps used in the system are detailed; the planner can view an overview map that shows an entire route.

tion of travel times is an important factor for assigning tasks, errors can have serious effects on the plans created. In one example, the calculated transport time was 25 minutes; the actual time was 5 minutes. Thus, we had to modify the maps manually. We developed sophisticated tools to make this step more efficient. In Figure 4, we illustrate an overview map; in Figure 5, we show a detailed view. A printed detailed map is useful to staff members when they must travel to new areas.

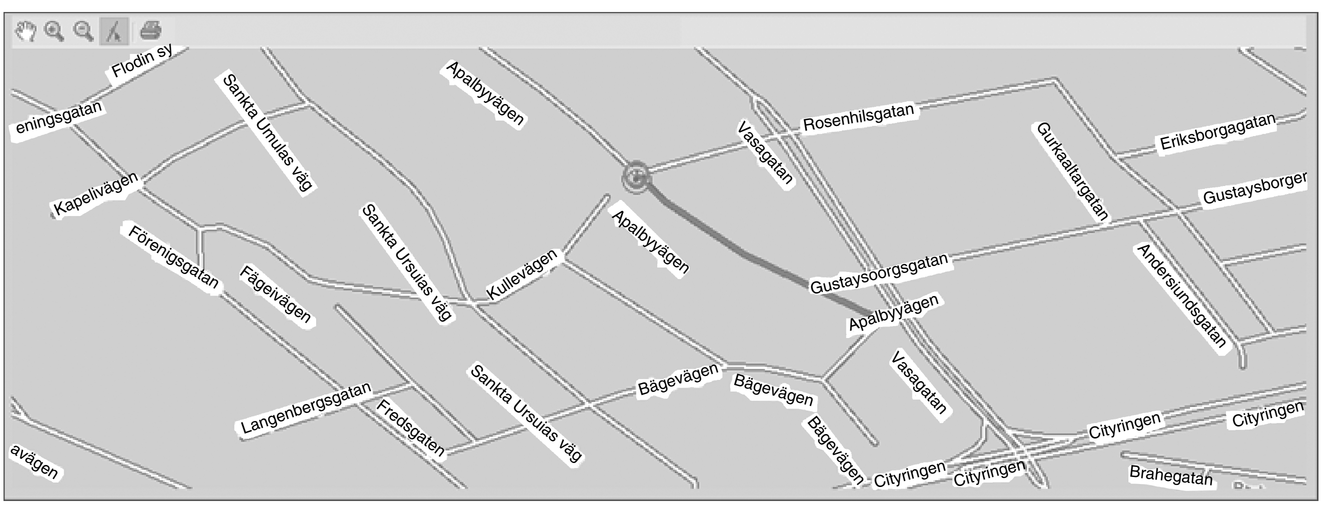


Figure 5: The route can also be viewed such that it displays only a few streets to show the location of client houses in detail.

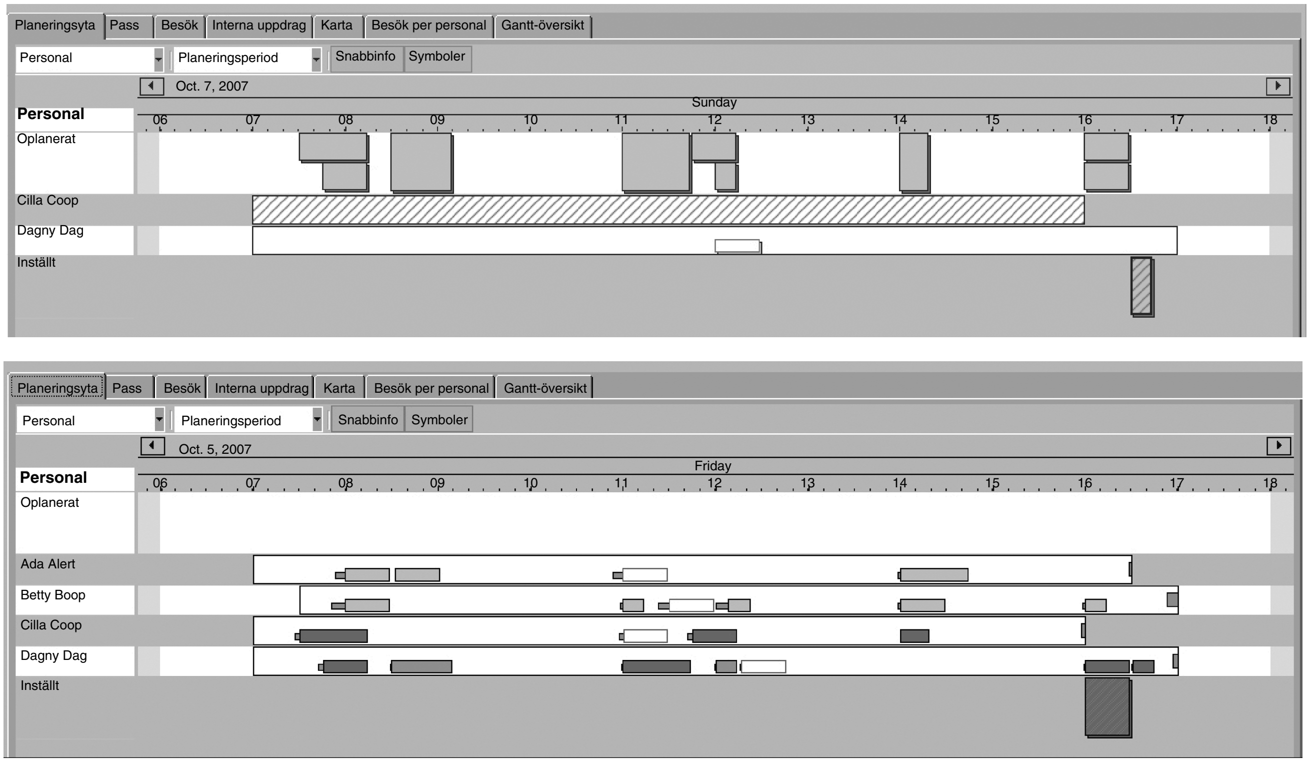
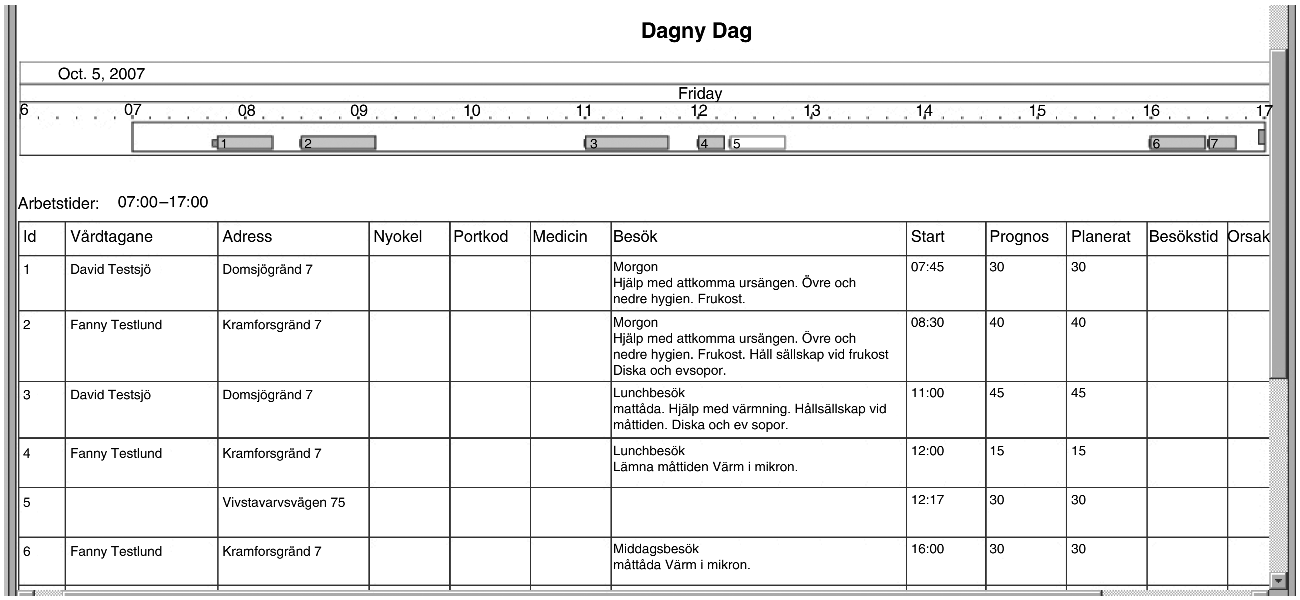


Figure 6: The planning process begins with a set of visits that are not assigned to any staff member (top). Once the optimization module has assigned the visits to staff members and scheduled these visits, it shows a solution to the planner (bottom). It also shows any unassigned visits; the planner may choose to rerun the optimization or manually insert a route. Therefore, the screen shots shown are before planning (top) and after planning (bottom) when all visits have been allocated to staff members. The larger boxes represent tasks; the thinner lines represent travel time.

When we designed the solution algorithms, our goal was to provide high-quality solutions within five minutes. Our experience from previous software projects using optimization algorithms has shown that users frequently tend to use the solution algorithms as a simulation tool; thus, they might want to create several alternative solutions by altering parameters slightly. The current solution time ranges between one and two minutes; therefore, a planner could easily test 5 to 10 scenarios within half an hour. We believe it is important to consider solution times as a restriction when constructing software for practical use. In Figure 6 we show two views. The first view (top) illustrates a no-visit situation; the second (bottom) shows a situation in which the optimization has produced a preliminary plan. It is also possible to drag and drop visits to staff members anywhere in time.

There are many possibilities for viewing and changing a solution. In Figure 7, we provide a sample of the printed version that the home care worker receives.

When designing the Laps Care user interface, it was important that we understood the needs of the target group because they control and use the optimization models in their daily work. The users have an extensive knowledge about the operations, their staff, and their clients; however, they do not have any operations research training or an engineering background. Laps Care is not a centralized planning system; each home care unit plans its operations locally. Stockholm has 800 planners. These planners are not full-time; however, they participate in performing the visits. Therefore, we decided early on that they would not see traditional optimization parameters. We wanted to let the planners express their



Dagny Dag

Oct. 5, 2007

Friday

Arbetstider: 07:00–17:00

Id	Vårdtagane	Adress	Nyokel	Portkod	Medicin	Besök	Start	Prognos	Planerat	Besökstid	Orsak
1	David Testsjö	Domsjögränd 7				Morgon Hjälp med attkomma ursängen. Övre och nedre hygien. Frukost.	07:45	30	30		
2	Fanny Testlund	Kramforsgränd 7				Morgon Hjälp med attkomma ursängen. Övre och nedre hygien. Frukost. Håll sällskap vid frukost Diska och evsopor.	08:30	40	40		
3	David Testsjö	Domsjögränd 7				Lunchbesök mattåda. Hjälp med värmning. Hållsällskap vid måttiden. Diska och ev sopor.	11:00	45	45		
4	Fanny Testlund	Kramforsgränd 7				Lunchbesök Lämna måttiden Värm i mikron.	12:00	15	15		
5		Vivstavarvsvägen 75					12:17	30	30		
6	Fanny Testlund	Kramforsgränd 7				Middagsbesök måttåda Värm i mikron.	16:00	30	30		

Figure 7: The printed schedule, which is provided to the staff members, also includes relevant information such as door codes, special requests, and phone numbers.

preferences in an as natural as possible way. Therefore, we express preferences in terms such as "desirable," "okay," and "not okay." We also reduced the mathematical interpretation of these weights and handled other criteria similarly.

Some goals, such as travel-time efficiency versus continuity, might be contradictory. The users can control such trade-offs by using slide bars, which, in this example, would have efficiency on one end of the bar and continuity on the other end. This is also educational because it shows that raising the focus on one goal will decrease the relative focus of another goal.

The software system must provide the necessary functionality to support the organizational processes it is intended to support. It is much more than just an efficient optimization routine. We did experience some challenges; for example, some planners did not use the scheduling optimization routine enough; instead, they used the manual drag-and-drop in the user interface, or the map was not detailed enough to include efficient bike routes and shortcuts. Therefore, we added the ability to allow planners to manually add such routes into the system. When Laps Care is a part of a full management system, identifying needs, such as staffing levels or staff competences, is critical, as is the need for integration with other operational systems.

Implementation

An organization that has not prepared for the work associated with introducing a DSS is less efficient than one that realized this need early in the process. Challenges for an efficient implementation of Laps Care can be divided into *System*, *Education*, *Support*, *Change Management*, and *Large-Scale Implementation*. We have described System above; below, we focus on the remaining issues and also some notes on *Public Tenders*.

Education

Providing the necessary user training is critical. Laps Care is a powerful system with many advanced features and powerful tools; unfortunately, the home care staff has relatively little computer experience. If planners do not receive sufficient training, they might not be able to utilize the system's full capacity. The organization must have a champion who will drive and motivate the installation.

The implementation project for the initial customers started with software training, and the planners registered all data. We verified the data by running Laps

Care and generating plans, but we used the manual planning process for execution. We compared the Laps Care plans to the manual plans to correct errors. This verification usually took two to four weeks; this is the cycle period in which all normal assignments occur at least once because each home care assignment happens at least once a month.

After this early training, most units started to use the system for their daily planning. However, some units required much longer to complete the verification and acceptance step. When we analyzed the reasons, we saw that the most common cause was that they had not obtained the results they expected from the DSS. This occurred because managers had not given the planners clear objectives. Planners were unsure of the appropriate goals and thus were unable to weigh the trade-offs necessary to optimize planning.

Examples of trade-offs that we had to address were conflicting goals, such as efficiency, staff continuity, meeting exact time windows, and even staff workload. A customer never works toward only one goal; each goal must be fulfilled to some level if plans are to be acceptable. However, when these goals were not clearly stated and communicated within the organization, the planner was in the difficult situation of trying to fulfill many conflicting requests. In the most successful projects, the manager stated and obtained acceptance of clear goals and then backed the planners when major decisions had to be made. To address this, we altered our implementation methodology and started each project by establishing a project plan that included establishing project goals. Although this might seem to be an obvious way to do an implementation, the organizational goals were often vaguely defined; this required that the organization clarify its operational priorities.

Support

The customer organization must ensure that surrounding processes fit the new way of working and that staff roles and responsibilities are defined clearly. Otherwise, members of the home care staff who only make visits and are no longer involved in the operational planning might feel less involved than they were. It was necessary to balance the traditional planning process with the new process, which is more centralized around one planner. Traditionally, the staff has been divided into separate groups, each working in only a section of the district. Laps Care allows employees to work in several areas, thus increasing flexibility and distributing uneven workloads among districts.

Early in the development process, Forum Laps Care was organized as a user forum. In a two-day session, users presented their Laps Care implementation experiences, discussed and shared possibilities and obstacles, and prioritized future development of the product. In its early years, this was a yearly event; however, as the number of users grew, local events were also arranged. Several benefits accrued; users shared good advice about the implementation process, individuals who were part of an early implementation phase received support, users provided (and received) practical examples of what an implementation could achieve, and users were able to influence future development.

Forum Laps Care includes all Laps Care customers—about 200 customers, in addition to 800 units the City of Stockholm, will have been added by the end of 2008. The City of Stockholm has created its own user association that provides feedback on an extensive development effort, which is associated with both Laps Care and its related support system. The association has its own website with product information; it also conducts two annual two-day meetings. In the future, we expect that this user association will merge with the Forum Laps Care. In addition to Forum Laps Care, several customers meet on a regular basis to share experiences and their solutions to various planning problems.

Change Management

The home care units that introduce Laps Care must formulate their implementation goals. However, the home care organization might not be prepared for the necessary changes. The following example illustrates the importance of change management. As part of the implementation, staff members were given an instruction to verify the system for a full cycle of two to four weeks, during which all the assignments would have occurred at least once. They were also instructed to check the plans daily to see that all assignments were included in the plan and correctly registered.

During the first week of operation, two assignments in the plan were missed. Rather than informing the planner, a group of four social care workers contacted the local paper, which published a highly negative article. Politicians began to react to employees leaving work during working hours. The negative publicity continued with a series of negative articles and events; there were political speeches, local public debates, church collections for the employees, and inspections from monitoring authorities. The project leaders endured the turbulence until the paper wrote a positive article a year later.

Understanding the actual reason for this situation is difficult. Immediately prior to the implementation, the organization had been undergoing some major changes, including new schedules and the merging of units. Some staff members were discontented and highly skeptical of further changes. This shows the importance of discussing the uses of a DSS and the reasons for introducing it with staff, rather than simply implementing it and agreeing on the process by which the organization moves from a manual planning system to an automated system.

Several issues emerged when we introduced the system; for example, some employees combined several tasks into one. In one example, an employee collected the laundry for three clients and washed it all at the same time. Although this is more efficient, the task of doing laundry also should involve spending time with the client. This employee's neglect of the socialization side of the task affected the quality of the service and was against policy. Laps Care also mitigated some issues. For example, senior staff members traditionally have kept the "good" tasks for themselves and left harder tasks for new, part-time, or extra staff. This often created an unfair situation; however, Laps Care optimized the scheduling to ensure that the schedules were fair to all individuals; thus, it removed this as an issue.

Large-Scale Implementation

Implementing the system in a large organization places new demands on both software and implementation. In the City of Stockholm, there will be 800 planning units and 15,000 staff members when the rollout is complete, with all units to a central back-end system. The objectives of introducing a planning system in a large organization or a single home care unit are basically the same. In a large organization, however, the system must be integrated with many other systems. The DSS and other systems must meet high-performance criteria for centralized maintenance and must provide efficient system administration, a clear structure for information exchange, a well-defined work flow, support for reporting and statistics, and support for continuous learning, for example, through Web-based e-learning. The operational requirements must be flexible and simple; this is a challenge when the organization has many users with differing information needs and demands. A large-scale implementation also means that there are additional people at various levels of the management who require aggregated information from the system.

The most expensive component of a home care unit is its personnel costs. The city's home care units spent a great deal of time in creating the complex personnel-scheduling system, which optimizes the use of the personnel resources in scheduling visits. The system schedules each care-worker visit according to plans and agreements registered in the city's back-end system. The city had invested in a large-scale development of ICT-based systems, which have been in use since 2004. However, any change in organization and service demands brings about a need for adjustments and new functions; for example, the back-end system used in the social care activities required development. Integration between the various ICT solutions represented a major part of this extended development. The objective was to connect these systems and create an information flow between them. Using mobile devices connected to the master systems, personal journals, and the planning system, the care worker in the field would be able to access information whether at the desk or out of the office (Figure 8).

Secure ICT solutions make information available and accessible. For many of the thousands who work in home care, a mobile device is the only unit they need. Core concerns in system development include the business process and information structure. Representatives from the personnel working in social care analyzed the current business processes and developed improved versions to increase their effectiveness and productivity.

For a year, TietoEnator, Linköping University, the Linköping Municipality, and the City of Stockholm

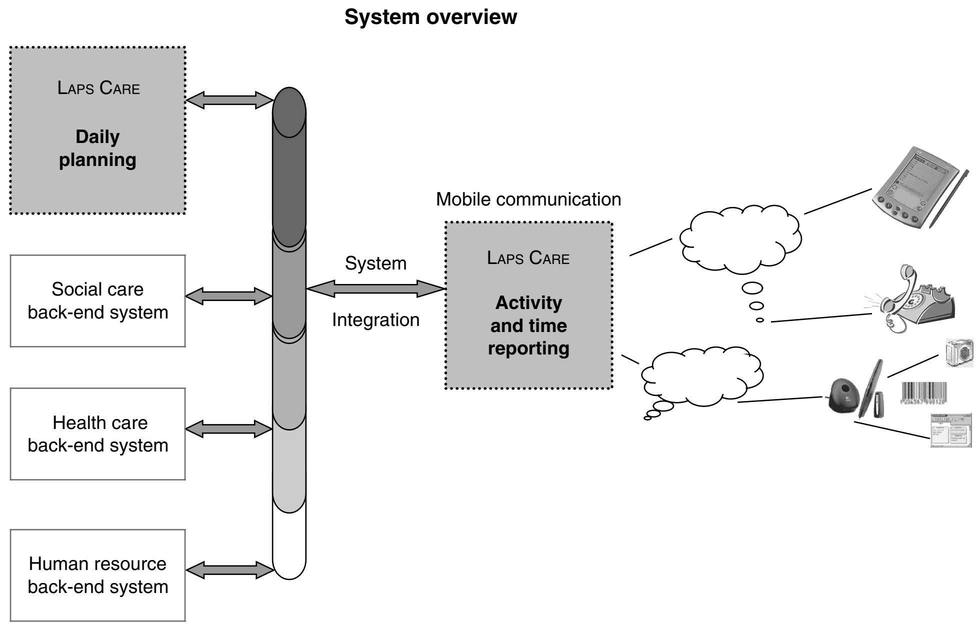


Figure 8: The ICT system that the City of Stockholm implemented integrates with several information systems. In addition, the system includes a mobile communication system connecting all staff members.

worked together to evaluate the introduction of LAPS CARE in other large municipalities. The evaluation project influenced LAPS CARE Version 3, which has now been released in the Nordic market. In addition to being a leading planning system, it now includes a revised education model, an e-learning module, an integration module, and mobile support for documentation and time reporting.

Quantifiable Benefits

When we describe the benefits of LAPS CARE, we base them on different sources. The members of Forum LAPS CARE have published many detailed analyses, including one that the Linköping Municipality provided. As of the beginning of 2009, more than 900 units in Sweden, Norway, and Finland use LAPS CARE. On average, there are 15–30 employees in a unit; they make an average of 150–200 visits each day. The system schedules approximately 15,000 staff members each day. Many units in the City of Stockholm have used the system for several years, and some detailed analyses exist. In 2004, the IT University in Stockholm evaluated the viability of using different ICT solutions in elder care activities in the city.

Based on its evaluation and one detailed analysis performed by three district councils, the quantifiable savings realized will be in two primary areas: documentation, and the coordination and planning of daily activities. Monetary savings will continue each year and will increase or decrease based on the number of work orders performed with the elderly or disabled citizens. Based on cost calculations the first-year savings will offset the one-time investment cost. The latter was the basis for making the decision to roll out all 800 units and 15,000 staff members. This rollout started in 2008 and will be finished during 2009. In addition, new customers in Sweden, Norway, and Finland began LAPS CARE implementations during 2008. We present below the results based on customer evaluations. The reports are not standardized; each report focuses on different areas. We have included all quantifiable figures from the available reports.

Monetary Savings

Among the current customers within Forum LAPS CARE and its 200 units, we estimate the yearly savings to be approximately 20–30 million euros ($30–$45 million). In the City of Stockholm, 10 units have been in operation for several years. By the beginning of 2009, all units were expected to be in operation. The estimated cost savings (based on detailed study of some existing units) for all units in the City of Stockholm are 20–30 million euros ($30–$45 million). For the total customer base, the confirmed sales and those planned for 2008–2009 will add another 30 million euros ($45 million) in savings. In addition to the direct savings from Laps Care, there are indirect savings, such as time reporting, field documentation, and integration with the enterprise resource planning (ERP) system, navigation, and emergency telephone services. We estimate these savings to be approximately 20–30 million euros ($30–$45 million). Overall, the total monetary savings in 2009 are expected to be approximately 90–120 million euros ($135–$180 million).

Increased Efficiency

Customers used two measures to measure efficiency: staff utilization rate and planning time. Halmstad Municipality, which has used Laps Care in three units since 2003, improved efficiency by 12 percent—staff made 12 percent more visits in the same number of working hours. In addition, the competence match between staff and clients improved. In the Bengtsfors Municipality, which has used the system since February 2005, the staff productivity rate in one unit increased by 10 percent. The Jakobsberg Municipality did a detailed analysis of Laps Care's effects during a two-week period in 2005. Its staff productivity rate increased from 47 percent to 68 percent. Aurskog-Høland Municipality, the first unit in Norway to use Laps Care, measured its staff productivity improvement at 12.5 percent; this is equivalent to an additional 30 minutes of care daily by each staff member. In Linköping, the staff productivity rate increased by 6.4 percent between 2006 and 2007; it attributes half the productivity increase to Laps Care use. Its planning time has decreased from 45 minutes to 18 minutes per staff member per day. This corresponds to 8.15 full-time employees or 300,000 euros per year. Halmstad decreased its weekly planning time from 15 to 5 hours; in Bengtsfors, morning meeting times have decreased by two-thirds; this represents 2,000–2,500 hours per year. Its overall planning time has decreased by 1,000 hours per year. In Jakobsberg, the planning time was reduced from 23 to 14 hours during a two-week period. In the City of Stockholm, the estimated time spent in developing schedules for each of the 15,000 care workers in the city's home help units was reduced by an average of 10–12 minutes each day. On an annual basis, this corresponds to 310–375 full-time staff members working for one year.

Transportation

In Bengtsfors, the driving distance is 20 percent lower than previously, partly because the planner can simulate different car-pooling options.

Budgeting Accuracy

In Linköping, a survey among managers in October 2007 showed that 100 percent stated that they had better control of the budget and could better assign staff levels against actual demand using Laps Care.

Sick Leave

In Jakobsberg, the annual short-term sick leave fell from 563 days to 166. Several other sites also reported decreased short-term sick leave. This result was somewhat unexpected; however, an explanation might be that the daily situation is less stressful because the routes are feasible, allowing time for travelling, and that the work load is evenly distributed among all staff members.

Quality and Safety

In Jakobsberg, the number of missed visits (forgotten, delayed, or rebooked) fell from 91 to 4. Halmstad reported that the number of staff members per client decreased, as did the risk of missing client assignments. In Bengtsfors, where staff had previously had many discussions about which staff member should perform which visit, these discussions almost ceased because the system is totally objective. This has led to less stress and a quicker introduction to the work for new staff members.

Aurskog-Høland employs highly qualified nurses; better skill matching allows 22 percent of the nurses to be used for work requiring their specific skills. Whereas the previous planning system based visits on their geographical location, Laps Care considers the proper use of skills and arrival times.

Unquantifiable Benefits

The introduction of Laps Care affected several groups, including clients, staff, planners, and unit managers who are closest to the operations. Moreover, during recent years, all public tenders have required the software to include an optimization module; this benefits the OR community. Stakeholders also include higher-level managers and politicians in the municipalities. We list below the different roles and the benefits they receive from Laps Care.

Clients

The implementation of an improved planning system significantly reduces the risk of home care staff forgetting visits. In addition, a feasible plan allows the clients to receive the service and care to which they have a right. The system makes it easier to ensure continuity in terms of specific staff members visiting specific clients; thus, it reduces the number of different faces the client sees. This, in turn, increases the quality of the service offered. The system provides reports to clients and relatives when client and home care organization revise the care plan. The reporting makes it possible to compare the overall care hours and number of different staff members (who visit the client) to the plan.

Staff

Many employees find working in the home care sector to be stressful. The removal of the often-turbulent last-minute morning meetings has removed one stress factor. Several customers have seen significant drops in short-term sick leave because of the reduced stress, as we discussed previously in the *Sick Leave* section. Creating routes that facilitate fair distribution of work among staff members and allow for realistic travel times between visits has also alleviated stress. A clear description of the visits provides security for both regular and temporary staff and enables collaboration between groups. The system can also schedule work tasks, such as meetings, documentation, and administration. It provides facts as a basis for discussion among all staff members. Better usage of employee skills also raises the sense of satisfaction and professionalism among the home care workers. The system provides detailed information about each staff member's workday. Although critics contend that this has taken away some individual freedom and responsibility and has increased the power of the planners, the improved processes and routines have motivated the staff to become a part of the planning process.

Planners

Laps Care includes all the information that planners need to perform their tasks. For example, the ability to run simulations and perform "what-if scenarios" allows planners to prepare for the occurrence of many potential situations and to adjust operations based on these situations. It also allows planners to meet individual staff preferences more satisfactorily, while still maintaining fairness in scheduling staff members. The use of printed schedules with detailed instructions and maps simplifies the work of new staff.

Unit Managers

Unit managers gain a better overview and control of their clients and their own organization, and thus they can do better long-term staff planning. Laps Care also provides better financial and budget control. Managers can find problems in work routines, discover injustices among the staff, and establish a better working environment. Laps Care also allows them to compare planned time and actual operations and change work routines and travel behavior. Using a manual planning system made it difficult for them to understand the amount of time staff actually spent in travel. Laps Care provides these travel-time estimates. It also provides reports that summarize each day's activities. According to Swedish regulations, all work done must be registered—a requirement that had previously been difficult to meet. Surveys show clearly that managers who use the system more actively are more positive about the results and their experiences with the system.

Managers in the Municipality

Laps Care significantly improves planning, follow-up, and prioritization tasks for high-level managers. Based on the information provided, they can, for example, determine savings or allocate extra resources. It provides a better basis for budgeting and evaluating long-term changes in staff and client needs. Managers can follow the staff usage level on a daily basis in a very dynamic environment. Problems with work environments and routines become clear; thus, they are easier to resolve. The system also makes it easier to raise ethical fact-based discussions on operations.

Politicians

When determining economic budgets for the home-care operations, the information provided forms a basis that allows politicians to make decisions. They can also more easily show the items on which they spend taxpayer money and demonstrate that they are using it efficiently.

City of Stockholm Organization

By making the best possible use of employee time, and by implementing new ICT-based solutions for the planning and documentation of the daily social care activities, the City of Stockholm makes an investment in higher quality and creates a cost-effective organization. New and more effective documentation and planning routines lead to better use of personnel time and a higher level of security for the elderly citizens being served. The staff does not waste time waiting for new assignments or travelling between different locations, because the planning and routes are optimized and the mandatory journal is updated throughout the day. Therefore, the staff has more time for actual home care work.

The latest version of Laps Care includes support for documentation, time measurement, and direct reporting of operational work. New technological tools—such as short message service (SMS), digital pens, mobile phones, and PDAs—are available to staff. In addition, Laps Care can be integrated with other technical and process-oriented systems.

Nonmonetary benefits include the standardization of information registered across the city's home care units. This enables executive-level management to efficiently search information in the organization because the data are in a single database that uses a standard data format. The information is also used for quality follow-ups and benchmarking activities. Quality information leads to better and improved management coordination and decision making.

Well-performed and planned social care gives an elderly citizen a feeling of safety and security. In recent years, the social care tasks have changed tremendously. Elderly citizens need more help and often rely on home care as an alternative to hospitalization or nursing homes. The daily plan must consider medical instructions and time limits as well as any special qualifications needed when it assigns a care worker. Planning the home care unit's work to ensure that every citizen in need of help gets service as planned, and that the personnel know what, how, when, and where they are supposed to go, produces an efficient and well-run system that, in turn, results in that feeling of security and safety to the clients.

Laps Care is used to coordinate the activities for elderly citizens and disabled persons living in their own apartments or houses. The personal journals and decisions relating to specific services are registered in the back-end system; this information is available in Laps Care through information flow between the various system databases.

In every home care unit, one or two people are responsible for administrating the planning using Laps Care. New plans are made daily and, if necessary, more than once a day. The city's map is integrated into Laps Care and supplies both address information and the calculated time needed to reach an appointed assignment.

Concluding Remarks

Planning systems for home care and home health care are of increasing interest. The use of OR-based ICT solutions for planning has resulted in both security and efficiency in the city's most important activity. Quality social care demands extended personnel time and flexible planning. Better planning, especially for the home care units, is a good example of how ICT can make a difference and increase both efficiency and quality. Information should be both easily accessible and reliable, whether a care worker is working in an office or providing service in an elderly person's home. Evaluations and experience show that both employees and the elderly or disabled citizens receiving care benefit from the use of modern ICT solutions. The employees save time, create information, and access instructions throughout the day. The savings from using the system are large; the 2008 estimate is 50–70 million euros ($75–105 million). At the same time, there will be a large number of new Laps Care customers as the elderly population grows and more organizations implement the system.

A key part of Laps Care is an optimization module that establishes feasible and efficient plans in short solution times. This makes it possible to increase the quality for both clients and staff by scheduling an employee with the appropriate competence to visit an elderly client. The decreased planning time also has a direct impact on the available work time for each staff member because last-minute changes or discussions are removed. We took special care to ensure that the optimization models are easy to control because we realize that most planners do not have OR backgrounds.

During 2008, the number of units exceeded 1,200 and the number of employees scheduled on a daily basis was close to 20,000. Considering committed orders, we expect this to increase to 1,500 units and 30,000 employees during 2009. Because the number of home care workers in Sweden alone exceeds 120,000, there is potential to find many more users for Laps Care. Home care is also organized in a similar way in other north European countries, a region that has more than one million home workers.

Laps Care has been recognized for its usefulness in different organizations. It was given the 2002 IT Innovation in Health Care award by *Dagens Medicin*, a Swedish medical journal, and became a finalist in 2003 Users Awards by The Swedish Confederation for Professional Employees/The Swedish Trade Union Confederation (TCO/LO), two major Swedish labor union organizations. In 2003, it received The EURO Excellence in Practice Award.

Appendix

Model

The basis for the modeling is a set-partitioning model. To solve this we tried several approaches, including branch and price (i.e., column generation with branch and bound). However, the solution we adopted is based on a repeated matching algorithm in which the routes are represented as columns in the set-partitioning model. As a basis, we make use of a set-partitioning model with the following index sets and variables.

I: set of staff members.

J_i: set of schedules for staff member i.

V: set of visits.

$x_{ij} = 1$ if staff member i uses schedule j, 0 otherwise.

To use the variables, we also need the following information.

c_{ij} = cost for staff member i using schedule j.

a_{ijv} = 1 if staff member i does visit v in schedule j, 0 otherwise.

The cost c_{ij} is made up of all components, such as travel time, travel costs, scheduled hours, inconvenient working hours, and preferences. The cost is not a pure-dollar cost; instead, we use a weighted-objective function. We can now state the model as

$$\min \quad z = \sum_{i\in I}\sum_{j\in J_i} c_{ij}x_{ij} \tag{1}$$

$$\text{s.t.} \quad \sum_{j\in J_i} x_{ij} = 1, \quad \forall\, i \in I, \tag{2}$$

$$\sum_{i\in I}\sum_{j\in J_i} a_{ijv}x_{ij} = 1, \quad \forall\, v \in V, \tag{3}$$

$$x_{ij} \in \{0, 1\}, \quad \forall\, i \in I,\ j \in J_i. \tag{4}$$

The generalized upper-bound constraints (2) force each person to select exactly one schedule. Constraints (3) state that each visit must be included in a chosen schedule. Equations (4) are binary restrictions on the decision variables. The number of potential schedules is very large. In this model, we cannot consider the synchronization aspect when two staff members are required simultaneously; this is handled separately in the repeated matching heuristic.

Acknowledgments

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